

## CLAIMS

What is claimed is:

1. A method for establishing an acceleration of a vehicle, comprising the steps of:
  - 5 establishing a gravity vector representing acceleration due to gravity;  
measuring acceleration of the vehicle in a first direction and establishing a first acceleration value;  
measuring acceleration of the vehicle in a second direction and establishing a second acceleration value, the first and second directions being  
10 perpendicular; and,  
establishing a magnitude of a horizontal component of the acceleration of the vehicle as a function of the gravity vector and the first and second acceleration values.
2. A method, as set forth in claim 1, wherein the horizontal component of the acceleration is in a plane defined by the first and second directions.
- 15 3. A method, as set forth in claim 1, wherein the step of establishing the first acceleration value includes the step of applying a first offset value and wherein the step of establishing the second acceleration value includes the step of applying a second offset value.
- 20 4. A method, as set forth in claim 2, including the step of establishing the first and second offset values using a calibration routine.

5. A method, as set forth in claim 3, the steps of measuring the acceleration of the vehicle being performed by an accelerometer device, the accelerometer device for providing first and second output signals corresponding to acceleration of the device in first and second accelerometer directions, the first and second accelerometer directions being perpendicular, the calibration routine being performed when the accelerometer device is not moving and including the steps of:

reading the first and second output signals when the accelerometer device is in a first position;

rotating the accelerometer device 180 degrees to a second position;

10 reading the first and second output signals when the accelerometer device is in the second position; and,

determining the first and second offset values as a function of the first and second signals read when the accelerometer device is in the first position and the first and second signals read when the accelerometer device is in the second position.

15 6. A method as set forth in claim 4, the first and second offset values being determined by:

$$X_0 = (X_1 + X_2) / 2, \text{ and}$$

$$Y_0 = (Y_1 + Y_2) / 2,$$

20 where  $X_0$  is the first offset value,  $X_1$  is the first output signal read when the accelerometer device is in the first position,  $X_2$  is the first output signal read when the accelerometer device is in the second position,  $Y_0$  is the second offset value,  $Y_1$  is the second output signal read when the accelerometer device is in the first position, and  $Y_2$  is the second output signal read when the accelerometer device is in the second position.

7. A method, as set forth in claim 4, wherein the accelerometer device is a two-axis device which consists of an integrated circuit that contains both x and y accelerometer functions.

8. A method, as set forth in claim 4, the calibration routine further including  
5 the step of calculating a scaling factor as a function of the first and second signals read when the accelerometer device is in the first position and the first and second signals read when the accelerometer device is in the second position.

9. A method, as set forth in claim 7, where the scaling factor is calculated using:

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$$K = ((X_2 - X_1)^2 + (Y_2 - Y_1)^2) / 4,$$

where K is the scaling factor,  $X_1$  is the first output signal read when the accelerometer device is in the first position,  $X_2$  is the first output signal read when the accelerometer device is in the second position,  $Y_1$  is the second output signal read when the accelerometer device is in the first position, and  $Y_2$  is the second output signal read  
15 when the accelerometer device is in the second position.

10. A method, as set forth in claim 7, where the scaling factor is calculated using:

$$K = G^2, \text{ wherein } G \text{ is the magnitude of the gravity vector.}$$

11. A method, as set forth in claim 1, wherein the steps of measuring the  
20 acceleration of the vehicle being performed by an accelerometer device, the accelerometer device for providing first and second output signals representing

acceleration of the device in first and second accelerometer directions, respectively, the first and second accelerometer directions being perpendicular, the step of establishing a gravity vector including the steps of:

- (a) reading the first and second output signals; and,
- 5 (b) determining a new gravity vector as a function of a previous gravity vector the first and second output signals and a low pass filter with a predetermined time constant.

12. A method, as set forth in claim 11, the new gravity vector having first and second components, the first and second components of the new gravity vector
- 10 determined by:

$$G_X = (1 - (1/A)) \cdot G_{OLD\_X} + (x / A), \text{ and}$$

$$G_Y = (1 - (1/A)) \cdot G_{OLD\_Y} + (y / A),$$

- where  $G_X$  is the first component of the new gravity vector,  $A$  is a predetermined constant,  $G_{OLD\_X}$  is a component of the previous gravity vector,  $G_Y$  is the second component of the
- 15 new gravity vector,  $G_{OLD\_Y}$  is a second component of the previous gravity vector,  $x$  is the measured acceleration in the first direction and  $y$  is the measured acceleration in the second direction.

13. A method, as set forth in claim 11, the time constant being about 4 milliseconds.

- 20 14. A method, as set forth in claim 1, wherein the horizontal component of the acceleration is determined by:

$D = |\mathbf{G} \times \mathbf{R}| / (G)$ , where  $D$  is the horizontal component of the acceleration,  $\mathbf{G}$  is the gravity vector,  $\mathbf{R}$  is measured acceleration during a braking event, and  $G$  is the magnitude of the gravity vector.

15. A method, as set forth in claim 1, wherein the horizontal component of the  
5 acceleration is determined by:

$D = |\mathbf{G} \times \mathbf{R}| / (G^2)$ , where  $D$  is the horizontal component of the acceleration,  $\mathbf{G}$  is the gravity vector,  $\mathbf{R}$  is measured acceleration during a braking event, and  $G$  is the magnitude of the gravity vector.

16. A method, as set forth in claim 1, wherein the horizontal component of the  
10 acceleration is determined by:

$D = |((Y_D \bullet X_G) - (X_D \bullet Y_G) / (G))|$ , where  $D$  is the absolute value of the magnitude of the horizontal component of the acceleration,  $X_D$  is the measured acceleration in the first direction,  $Y_D$  is the measured acceleration in the second direction,  $X_G$  is a first component of the gravity vector,  $Y_G$  is a second component of the gravity  
15 vector, and  $G$  is the magnitude of the gravity vector.

17. A method, as set forth in claim 1, wherein the horizontal component of the acceleration is determined by:

$D = |((Y_D \bullet X_G) - (X_D \bullet Y_G) / (G^2))|$ , where  $D$  is the absolute value of the magnitude of the horizontal component of the acceleration,  $X_D$  is the measured  
20 acceleration in the first direction,  $Y_D$  is the measured acceleration in the second direction,  $X_G$  is a first component of the gravity vector,  $Y_G$  is a second component of the gravity vector, and  $G$  is the magnitude of the gravity vector.

18. A method, as set forth in claim 1, wherein the horizontal component of the acceleration is determined by:

$D = ((Y_D \bullet X_G) - (X_D \bullet Y_G) / (G))$ , where D is the horizontal component of the acceleration,  $X_D$  is the measured acceleration in the first direction,  $Y_D$  is the measured acceleration in the second direction,  $X_G$  is a first component of the gravity vector,  $Y_G$  is a second component of the gravity vector, and G is the magnitude of the gravity vector.

19. A method, as set forth in claim 1, wherein the horizontal component of the acceleration is determined by:

$D = ((Y_D \bullet X_G) - (X_D \bullet Y_G) / (G^2))$ , where D is the horizontal component of the acceleration,  $X_D$  is the measured acceleration in the first direction,  $Y_D$  is the measured acceleration in the second direction,  $X_G$  is a first component of the gravity vector,  $Y_G$  is a second component of the gravity vector, and G is the magnitude of the gravity vector.

20. A system for establishing an acceleration of a vehicle, comprising:  
an accelerometer device for measuring acceleration of the vehicle in a  
first direction and responsively establishing a first acceleration value and for measuring  
5 acceleration of the vehicle in a second direction and responsively establishing a second  
acceleration value, the first and second directions being perpendicular;  
a controller coupled to the accelerometer device for establishing a gravity  
vector representing acceleration due to gravity and for establishing a magnitude of a  
horizontal component of the acceleration of the vehicle as a function of the gravity vector  
10 and the first and second acceleration values.

21. A system, as set forth in claim 20, wherein the horizontal component of  
the acceleration is in a plane defined by the first and second directions.

22. A system, as set forth in claim 20, the controller for applying a first offset  
to the measured acceleration of the vehicle in the first direction and for applying a  
15 second offset to the measured acceleration of the vehicle in the second direction.

23. A system, as set forth in claim 22, the controller for determining the first  
and second offset values using a calibration routine.

24. A system, as set forth in claim 23, the controller for performing the  
calibration routine while the accelerometer device is not moving, the calibration routine  
20 including the steps of reading the first and second output signals when the accelerometer  
device is in a first position, rotating the accelerometer device 180 degrees to a second

position, reading the first and second output signals when the accelerometer device is in the second position, and determining the first and second offset values as a function of the first and second signals read when the accelerometer device is in the first position and the first and second signals read when the accelerometer device is in the second position.

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$$X_0 = (X_1 + X_2) / 2, \text{ and}$$

$$Y_0 = (Y_1 + Y_2) / 2,$$

          where  $X_0$  is the first offset value,  $X_1$  is the first output signal read when the  
10   accelerometer device is in the first position,  $X_2$  is the first output signal read when the accelerometer device is in the second position,  $Y_0$  is the second offset value,  $Y_1$  is the second output signal read when the accelerometer device is in the first position, and  $Y_2$  is the second output signal read when the accelerometer device is in the second position.

26.    A system, as set forth in claim 24, wherein the accelerometer device is a  
15   two-axis device which consists of an integrated circuit that contains both x and y accelerometer functions.

27.    A system, as set forth in claim 26, the calibration routine further including the step of calculating a scaling factor as a function of the first and second signals read when the accelerometer device is in the first position and the first and second signals read  
20   when the accelerometer device is in the second position.

28.    A system, as set forth in claim 26, where the scaling factor is calculated using:

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$$K = ((X_2 - X_1)^2 + (Y_2 - Y_1)^2) / 4,$$

where K is the scaling factor,  $X_1$  is the first output signal read when the accelerometer device is in the first position,  $X_2$  is the first output signal read when the accelerometer device is in the second position,  $Y_1$  is the second output signal read when the accelerometer device is in the first position, and  $Y_2$  is the second output signal read when the accelerometer device is in the second position

29. A system, as set forth in claim 22, where the scaling factor is calculated using:

$$K = G^2,$$

10 where K is the scaling factor, and G is the magnitude of the gravity vector.

30. A system, as set forth in claim 20, the controller establishing the gravity vector by (a) reading the first and second output signals, and (b) determining a new gravity vector as a function of a previous gravity vector, the first and second output signals, and a low pass filter with a second predetermined time constant.

15 31. A system, as set forth in claim 30, the new gravity vector having first and second components, the first and second components of the new gravity vector determined by:

$$G_X = (1 - (1/A)) \cdot G_{OLD\_X} + (x/A), \text{ and}$$

$$G_Y = (1 - (1/A)) \cdot G_{OLD\_Y} + (y/A),$$

20 where  $G_X$  is the first component of the new gravity vector, A is a predetermined constant,  $G_{OLD\_X}$  is a component of the previous gravity vector,  $G_Y$  is the second component of the new gravity vector,  $G_{OLD\_Y}$  is a second component of the

previous gravity vector,  $x$  is the measured acceleration in the first direction and  $y$  is the measured acceleration in the second direction.

32. A system, as set forth in claim 30, the predetermined time constant being about 4 milliseconds.

5 33. A system, as set forth in claim 20, wherein the horizontal component of the acceleration is determined by:

$D = |\mathbf{G} \times \mathbf{R}| / (G)$ , where  $D$  is the horizontal component of the acceleration,  $\mathbf{G}$  is the gravity vector,  $\mathbf{R}$  is measured acceleration during a braking event,  $\mathbf{G} \times \mathbf{R}$  is the cross product of vectors  $\mathbf{G}$  and  $\mathbf{R}$ , and  $G$  is the magnitude of the gravity vector.

10 34. A system, as set forth in claim 20, wherein the horizontal component of the acceleration is determined by:

$D = |\mathbf{G} \times \mathbf{R}| / (G^2)$ , where  $D$  is the horizontal component of the acceleration,  $\mathbf{G}$  is the gravity vector,  $\mathbf{R}$  is measured acceleration during a braking event, and  $G$  is the magnitude of the gravity vector.

15 35. A system, as set forth in claim 20, wherein the horizontal component of the acceleration is determined by:

$D = |((Y_D \bullet X_G) - (X_D \bullet Y_G) / (G)|$ , where  $D$  is the absolute value of the magnitude of the horizontal component of the acceleration,  $X_D$  is the measured acceleration in the first direction,  $Y_D$  is the measured acceleration in the second direction,  $X_G$  is a first component of the gravity vector,  $Y_G$  is a second component of the gravity vector, and  $G$  is the magnitude of the gravity vector.

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36. A system, as set forth in claim 20, wherein the horizontal component of the acceleration is determined by:

$D = |((Y_D \bullet X_G) - (X_D \bullet Y_G) / (G^2))|$ , where D is the absolute value of the magnitude of the horizontal component of the acceleration,  $X_D$  is the measured acceleration in the first direction,  $Y_D$  is the measured acceleration in the second direction,  $X_G$  is a first component of the gravity vector,  $Y_G$  is a second component of the gravity vector, and G is the magnitude of the gravity vector.

37. A system, as set forth in claim 20, wherein the horizontal component of the acceleration is determined by:

$D = ((Y_D \bullet X_G) - (X_D \bullet Y_G) / (G))$ , where D is the horizontal component of the acceleration,  $X_D$  is the measured acceleration in the first direction,  $Y_D$  is the measured acceleration in the second direction,  $X_G$  is a first component of the gravity vector,  $Y_G$  is a second component of the gravity vector, and G is the magnitude of the gravity vector.

38. A system, as set forth in claim 20, wherein the horizontal component of the acceleration is determined by:

$D = ((Y_D \bullet X_G) - (X_D \bullet Y_G) / (G^2))$ , where D is the horizontal component of the acceleration,  $X_D$  is the measured acceleration in the first direction,  $Y_D$  is the measured acceleration in the second direction,  $X_G$  is a first component of the gravity vector,  $Y_G$  is a second component of the gravity vector, and G is the magnitude of the gravity vector.

39. A method for controlling a brake mechanism of a towed vehicle towed by a towing vehicle, comprising the steps of:

- establishing a gravity vector representing acceleration due to gravity;
- measuring acceleration of the towing vehicle in a first direction and
- 5 establishing a first acceleration value;
- measuring acceleration of the towing vehicle in a second direction and
- establishing a second acceleration value, the first and second directions being perpendicular;
- establishing a magnitude of a horizontal component of the acceleration of
- 10 the towing vehicle as a function of the gravity vector and the first and second acceleration values; and,
- controlling the brake mechanism of the towed vehicle as a function of the magnitude of the acceleration of the towing vehicle.

40. A system for controlling a brake mechanism of a towed vehicle towed by a towing vehicle, comprising:

- an accelerometer device for measuring acceleration of the vehicle in a first direction and responsively establishing a first acceleration value and for measuring acceleration of the vehicle in a second direction and responsively establishing a second acceleration value, the first and second directions being perpendicular; and,
- 20 a controller coupled to the accelerometer device for establishing a gravity vector representing acceleration due to gravity, for establishing a magnitude a horizontal component of the acceleration of the vehicle as a function of the gravity vector and the

first and second acceleration values, and for controlling the brake mechanism of the towed vehicle as a function of the magnitude of the acceleration of the towing vehicle.

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